United Nations E/CONF.93/BP.3

# Economic and Social Council

Distr.: General
14 December 2000

English only

**Seventh United Nations Regional Cartographic Conference for the Americas**
New York, 22-26 January 2001
Item 7 (a) of the provisional agenda*
**Reports on achievements in surveying, mapping and charting in addressing national, subregional, regional and global issues, including policy and institutional issues**

## Economic issues in the evolution of national geospatial data infrastructure

**Submitted by the Secretariat****

* E/CONF.93/1.

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00-80224 (E) 080101

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# Economic Issues in the Evolution of National Geospatial Data Infrastructure.[1]



Richard Groot[2]

## 1.- Background.

Resolution 6 of the 15 th UN Regional Cartographic Conference for Asia and the Pacific held in Kuala Lumpur in April 2000 was passed to recognise that economic issues concerning modern National Surveying and Mapping, National Geospatial Data Infrastructure (NGDI), and Land Administration need to be given attention on the agendas of future UN Regional Cartographic Conferences. (Appendix 1). The main objective of the suggested Workshop on this subject, to be hosted by the Government of India, Ministry of Science and Technology, will be to attempt to map out the scope and priorities of the elements of this subject. This in turn will help to set specific agenda items and invite relevant papers in the UN Regional Cartographic Conferences.

In line with this, and taking advantage of the presence of two economists, the U. N. Economic Commission for Africa: - Ad- Hoc Group of Experts Meeting on "Study on the future orientation of the Geoinformation activities in Africa held from 6- 10 November 2000 in Addis Ababa, Ethiopia, included a meeting of a Working Group on Economic Aspects of Geoinformation[3]. In the half day available to the Working Group it attempted to take a first crack at mapping out the scope of the economics of geoinformation activities. Its draft report is attached as Appendix 2.

The present paper takes off from the results of the UNECA Working Group and tries to consolidate some of its questions with respect to the possible quantification of some of the convictions we hold so closely as self evident in the community of National Mapping Agencies (NMAs). These convictions are usually presented qualitatively and for those in our bureaucracies who do not share this self evidence, some economic quantitative calibration may be very useful, to get a sense of perspective on the importance of the work done by

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[1] Background paper for the 7 th United Nations Regional Cartographic Conference for the Americas, 22- 26 January, 2001, New York, USA.

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[3] I wish to recognize the contribution of all members of the Working Group to the stimulating discussion and to the encouraging results: Jacob Gyamfi- Aidoo, Liz Gavin, Pal Foyn Jespersen, and Helge Donnum

(NMAs). This in turn is likely to be useful in maintaining or increasing resources in support of essential national geoinformation activities. Hence illuminating the economic quantification of the assumptions made in supporting claims for budgets and regulatory initiatives must be seen as an important part of capacity building in NMAs.

The questions are presented as possible items for the agenda's of UNRCCs. Furthermore, as an example of an important aspect of the economics of geoinformation activities the results of an investigation into the requirements for efficiency in pricing and distribution of government's foundation data, under the constraints of certain normative government policy goals, together with the consequences for the corporate governance of National Survey Agencies will be presented as a case.

As it is impossible to deal with all aspects of national geomatics in the first part of this exercise, as suggested in the Kuala Lumpur Resolution 6, I have limited the content of this background paper to the production and dissemination of Foundation Data in the context of National Geospatial Data Infrastrucuture (NGDI).

**2.- Introduction**

Since the late 1980s a substantial literature has been built up of elements of the subject (National) Geospatial Data Infrastructure.((N)GDI). In the earlier part of this period the emphasize was not solely on the "national" aspect but on what the GDI concept is to achieve, namely the sharing of data and information once it had been collected. See for example Anderson (1990). This sharing could be imposed for example as a deliberate requirement of accountability by a manager for reasons of efficiency of information use within an enterprise, a municipality, a major project or routine activity crossing administrative, political or international boundaries etc.

The "national" focus gained prominence following the publication of the Executive Order concerning the coordination of geographic data acquisition and access in the United States Federal Government, Clinton (1994). It elevated the issue of National Spatial Data Infrastructure[4] from a technical subject to one being essential for the social and economic development of the country. Subsequently the Mapping Sciences Committee of the U. S.

National Academy of Sciences released three studies dealing authoritatively with the further development of this vision. See Mapping Sciences Committee (1990, 1993, 1994). In the early 90s the issue had, in the same context, also attracted the attention at the national and supra-national level in Canada, Australia , see for example Grant (2000) and New Zealand, and the European Commission. Many developing countries attempt to follow the institutional approach of the United States, mainly due to its excellent effort of keeping the world up to date with US developments through the newsletter and publications of the Federal Geographic Data Committee (FGDC) and the generous availability of their national standards documentation. At the subnational level, a very well documented case is the evolution of the geospatial data infrastruture of the province of New Brunswick, see for example Finley (2000).

Even though the Executive Order placed the NGDI in an important political, social and economic context, it is remarkable that research and publications on the financing and other economic issues in the evolution of NGDI have been relatively limited.

Here are some examples. Price Waterhouse (1995) presents a cost benefit estimate of the Australian land and geographic infrastructure activities. However, the 1: 4 relationship is at least subject to further research in terms of the uncertainties of the assumptions made in the calculations. Another attempt is reflected in Coopers and Lybrandt (1996), in which at least the monopolistic character of National Surveys received attention in terms of economic theory.

In Rhind (2000) an estimate was made of the budgets of the NMAs of Great Britain and the USA, which produce the foundation data for their respective NGDI, relative to the budgets of GIS applications. Thus he obtained a "proxi" for the reduction in transaction costs in the user community generated by the national foundaton data service activity. The estimates for the USA and the UK led to the same conclusion: the budgets of national Foundation Data providers are well below one percent of those of the direct clients collectively.

Another study dealt with the theoretical requirements for efficiency in the pricing and distribution of government foundation data, Groot (2001). Significantly for the national

[4] In the sequel of this paper the term National Geospatial Data Infrastructure (NGDI) shall be used to indicate

surveys is that the analysis has also resulted in the definition of the management framework of their organisations in terms which provide a foundation for the discussion of their regulatory position. In many countries the latter is a complicated matter when confronted with their responses to privatization initiatives.

**3.-What is the interest of governments in efficient geospatial data supply?**

Governments need geospatial data, referenced and defined in the national context, to govern. Examples are in legislative and policy development, for the allocation and management of natural resources, for defence and public safety, in support of a variety of regulatory activities. More generally, good governance requires promoting the development and understanding of knowledge about the physical, economic and human geography of the nation. To satisfy these requirements, the data is organised in a national co-ordinate system or "geodetic datum", while the data definitions are made consistent for the whole country. There is often a temporal dimension as well recording how some feature has changed over time.

A key characteristic of these standardised government geospatial data is the possibility of multiple, often unpredictable, applications inside as well as outside government. These unintended benefits are, in economic terms, "positive externalities".

At the most senior levels of government, high expectations have been expressed about the beneficial effects of the 'information society' or 'information economy', for example, for the delivery of healthcare, transportation management, life-long learning, sustainable development[5], etc. The role of the private sector in providing the communications infrastructure and the so-called 'value-added' information services is emphasised strongly. Recognising that the government itself is a very large source as well as user of such data, efficient and easy access to these sources becomes a high priority. Hence these expressions of policy signal that facilitating access to government owned data results in increasing positive externalities and reducing transaction costs to society as whole. These expectations have been articulated in, for example, EC (1994), Clinton (1994), and in EC (1998).

In this context the notion of the sharing of existing data through Geospatial Data Infrastructures (GDI) emerges as a significant matter of efficiency, and also as a generator of

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the development of this terminology as for example reflected in: Groot and McLaughlin (2000)

[5] Addressing concurrently the economic and environmental dimensions of resource allocation and management.

positive externalities. See for example Branscomb (1982). Groot and McLaughlin (2000) define the purpose of GDI as facilitation of access to and responsible use of geospatial data at 'affordable' prices. GDI is seen in this respect as a generalised concept which can be implemented at the enterprise level, the level of broad application domains such as coastal zone management, urban management or physical planning, or in the national context. Fig. 1 shows the idea of GDI for the application domain Environment and Physical Planning.

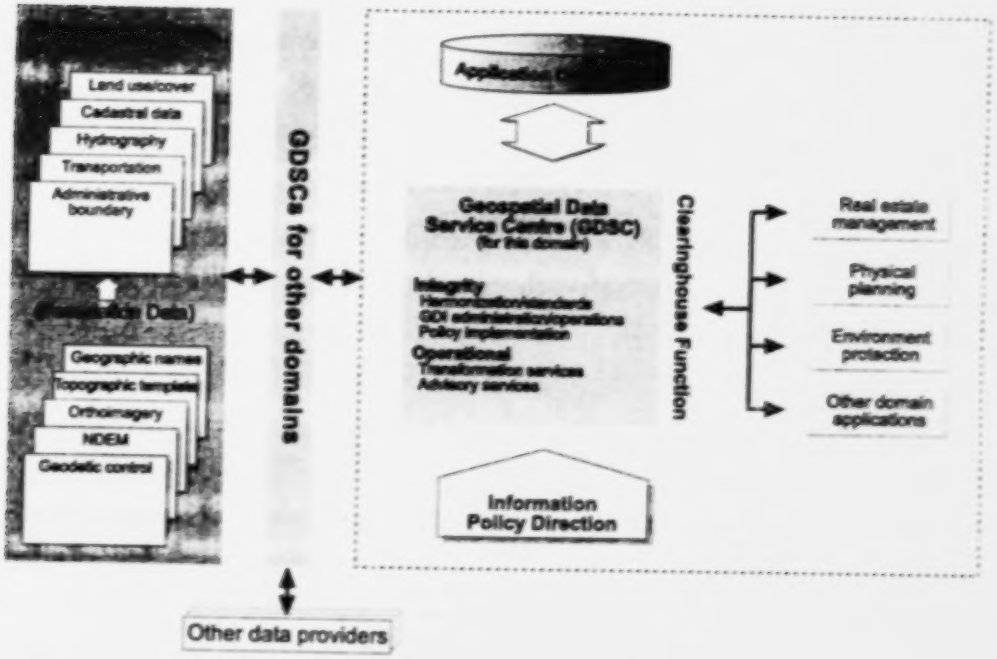


Fig. 1: The foundation data for the GDI in relation to the Geospatial Data Service Centre.

On the right hand side are the individual applications with their GIS systems, which all need routine supply of data. This stream of requirements is being met through a Geospatial Data Service Centre (GDSC). The GDSC harmonises / standardises all data for its application domain. It ensures they are described in a national meta data standard to facilitate the sharing of these resources by other potential users. The GDSC also enforces the information policies that control access, use and pricing, in keeping with legislation and overall government/ enterprise policy.

Generally speaking the National Surveys (Soil, hydrology, hydrography, vegetation, geology and geophysics etc.) are the relevant sources for the Framework Data. A special subset of these data is the Foundation Data (FD) which is the fundamental geographical reference for all other thematic application data. NMAs are usually responsible to produce, maintain and distribute the FD.

Within the context of the efficiency and effectiveness of government itself and the previously mentioned political expectations, optimal performance of NMAs and responsiveness to their client community is therefore obviously of paramount importance in reducing transaction costs in society. Since their inception (some as far as 400 years ago but most in the mid-1800's) they have enjoyed a monopoly in the technological and industrial organisation of national surveying and mapping activity.

Beginning in the mid-1970s, with the growing proliferation of Information Technology (IT), these monopolies were increasingly being challenged. The surveying and mapping technology has become increasingly embedded in software and accessible to non-specialists in the NMAs client community. Furthermore the client community obtained growing access to substitute products for the standardised topographic bases or thematic framework data sets (for example from Remote Sensing[6]). Both challenge the monopoly of the NMAs. Furthermore, the client community is increasingly changing to include for example GIS users interested in the digital data which are not the same as the digital form of the traditional topographic map content.

These effects of the ICT coincided with growing government deficits, which for most countries has led to a 20 year period of budget reductions, demands for revenue generation and, in the context of reform of government, privatisation. See for example Groot(1998). More importantly these radically changing circumstances led to critical review of the relevancy of existing and emergence of new mandates. See for example: Canadian Government (1986), Department of the Environment (1987), Mapping Sciences Committee. (1990), ANZLIC. (1996).

[6] Remote Sensing refers to Earth observation technologies from spaceborne platforms.

In spite of these studies NMAs all over the world have been slow in responding to these changes and many are experiencing major problems pushing through the restructuring necessary to move from automation to informatisation[7].

*Poor performance in terms of the content, quality, efficiency and timeliness of their products leads to the NMA's client community, especially the GIS community, falling back on cheaper and often simpler but more up to date substitute products from whatever sources may be available. This in turn leads to the loss of the positive externalities outlined above, to costly duplication, reduced and incompatible accessibility of existing (government owned) data, increased transaction costs and possibly reduced timeliness in decision making processes. In many ways it impedes full exploitation of ICT for the benefit of society in geospatial data applications.*

It is significant that in those countries where NMAs have successfully adapted to the dynamics of the ICT environment and the imperatives of government reform, the informatisation has been accompanied, and even led, by institutional and regulatory reform. The organisation was thereby placed in a regulatory environment in which both management and staff are motivated to be innovative and efficient and are rewarded for this. See for example Land Information New Zealand (1999).

**4.- Some selected economic issues.**

When considering the mission and mandates of a modern NMA, what would a thoughtful policy analyst ask to adsvise Ministers about the government's interest in the activity, what a reasonable funding level should be and to what extent innovation should be supported to improve effectiveness and efficiency of the organisation meeting the goals set for it by top level in government. She would probably address the problem by:

Two main points:

(a) Political and economic justification for investment by government in the collection and management of fundamental geo-information as a component of National Information and Communication Infrastructure (NICI)

[7] Automation: the introduction of IT to improve efficiency of existing production processes. Informatisation: the introduction of Information and Communication Technology (ICT) to respond to and develop new markets and client-oriented processes.

(b) Cost-efficient development, production and dissemination of geo-information

For the purpose of this paper and in the first instance our discussion here will be on the requirements for the foundation data production even though it is recognised that many NMAs have broader responsibilities than just that. There are of course interpretations of what the foundation data are in terms of content and scope. See for example Smith and Rhind (1999). However, for our purposes Fig 2b reflects what we shall assume to be foundation data.

4-1. The broader economic perspective.

First it should be accepted by Government that NMAs cannot be held accountable for the justification of their programs nor for their performance without some general policy guidance from the top level of Government. Government policy is in almost al cases politically inspired and thus normative, and economics cannot make a contribution in that. Once Government has declared its policy as for example in chapter 45 of this paper, economics may be a useful analytical tool to say something about the two points of interest to our policy analist.

In the broader economic perspective the markets for foundation data which describe the demand and supply functions take an important yet relatively unexplored subject. What are the characteristics of these markets? To what extent do they depart from the concept of perfectly competitive markets, for example due to the monopolistic position of the producing agency? What can be done to let the markets function as closely a possible to an open freely competitive market?

There may be distortions in the markets which may have other reasons but which nevertheless decrease efficiencies and thus increase costs. For example under the influence of donor driven programs an unrealistic demand may be met which will remain only as long as the subsidy by the donor remains in tact. When it stops the demand also dries up. This sometimes causes non-sustainability of the donor driven program.

4-2 The demand and the supply sides.

An important component influencing the demand is access to substitution. If the NMA does not deliver the required product to the quality and timeliness at a price the client considers

fair and is prepared to pay, the client will look for alternate ways to satisfy the requirement through substitution. In light of the growing penetration of affordable geospatal data production capabilities this is an option of increasing attraction especially to GIS clients. However, this may not be the case in the same measure in all countries.

In the past NMAs produced complex standard products that had to satisfy many different clients with one product. Increasingly they are now being asked to supply a diversity of geospatial data products and services on a custom made basis. If the foundation data are defined as geospatial objects and made available through object catalogues which basically are scale independent then a completely new production environment emerges which the NGA must design and implement. This will also influence the cost of the workflows, the pricing of products, the timeliness of delivery and the satisfaction of the clients. It is unfortunate that many NMAs especially in developing countries have great difficulty making this transformation. The question is if this is caused by defects in the markets or if the demand is simply not there yet and thus the basis for the necessary support for capacity building lacks. In almost all developing countries NMAs suffer for the lack of declared policy by government with respect to its expectations of the performance of its NMA in the context of declared demand in the NGDI. The performance parameters by which the agencies get measured, if at all have, no relationship to the demand in the NGDI. So how can the agency deploy? What can be done to break this deadlock?

As a result of this lack of clarity all NMAs suffer of the inability to safeguard budgets to adequate levels. They are easy targets for budget reduction exercises. To help reduce government deficits they often are instructed to introduce revenue generation. However, this conflicts with the demand of most parliamentary democracies that enlarging the budgets outside of the control of parliament is illegal. Hence their hard earned revenue goes to the general treasury and not to the organisation where the money could be used to up date plant and equipment, improve the reard systems etc. These are hardly encouraging conditions for management and staff to be innovative, efficient and client focussed. However, there are exceptions to these observations such as the Egyptian Survey Authority and the Ethiopian Mapping Agency which are, each in their own way, dealing with the newly evolving demands for their particular situations.

On the supply side price determination for products and services is a critical factor, altogether aside from important matters such as relevancy and timeliness of the product or service. Price setting depends on a fair and transparent calculation of the costs of all production input and processes. Few NMAs have, in their regulatory context of part of the Public Service, cost accounting systems in place which give answers to this. The tradition in government is to have cash flow control and line item budgets. The association of costs with products and services becomes therefore very problematic.

4.3 Results of UNECA working Group (Appendix 2)

When we consider these matters and combining this with the results of the Working Group (Appendix 2) A number of questions emerge which beg answering:

- In addressing the first point of our policy analist, we would encourage her to change the focus from collecting data and information to facilitating the development of the knowledge of the country as a whole by creating an environment in which access to and responsible use of geospatial information is facilitated at affordable costs. Howeever that implies also that there is a clientele that can in fact exploit this facility. This may mean introducing building capacity for this as early as primary school. Building knowledge and insight into the physical, social and economic geography of the country would support:
  - Good governance
  - Better allocation of resources and delivery of necessary services thereby contributing to poverty aleviation
  - Attract local and international investment
  - Expose the country's weak points but also its competitive advantage

Question: Intuitively we can get the analyst probably to get along with this. But is there any way to get a sense of the contribution of efficient and timely delivery of Foundation Data to these good things? In other words can these benefits be quantified?

Question: The claims about knowledge as reflected in point 52 of Appendix 2, can those be proven or quantified?

- On the subject of the imperfection of the markets for geoinformation or to be more specific for Foundation Data, Question: Is it possible to quantify the inefficiencies due to market imperfection?

On the subject of the positive externalities generated by the broadly available Foundation Data, Question: can externalities be quantified? Do estimates exist for availablity of Foundation Data for the market of value added products and services?

- Transaction costs

  These are the costs associated with obtaining and using a product, apart from the actual price paid, e.g.

  — cost of finding where to obtain information

  — cost of turning the data obtained into a product which is fit for intended use

Question: Is it possible to estimate reductions in transaction costs as a result of the timely availability of Foundation Data at reasonable cost?

- Cost recovery is a big issue with many governments. With respect to the Foundation Data,

(a) Question 1:

  — if a government is funding the gathering and management of foundation/framework data, should there be attempted cost recovery against demand from parties outside government?

(b) Question 2:

  — if cost recovery is not attempted, even in the longer term, what mechanisms can be used to ensure that a data producer is producing products on public money for which there is a real demand?

For possible answers see for example chapters 5 and 6 of this paper.

- As part of reducing the employment complement inside government and also hopefully in the interest of gaining efficiencies in production processes, there are many outsourcing initiatives for Foundation Data production:

Question: How far should one go with that until the asymmetry in information about production processes between government and private sector becomes so big that inefficiencies begin to occur due to increasing the overhead of control.

Thie is merely a start at identifying the questions that need to be answered to help executives of government and policy analysts to discuss in a constructive manner how the desire of governments for certain performance in the supply of Foundation Data can be justified and accomplished. One of the goals of this paper is to stimulate review of these questions and to see if other more relevant questions can be asked, with a view of attempting to get some answers.

## 5.- The requirements for efficiency in pricing and distribution of government geospatial data.

5-1. Key questions

While learning from the experience of regulatory reform for other natural monopolies, NMAs need to answer the following questions in developing their response to these new demands Groot(2001):

- What constitutes their Natural Monopoly in the ICT environment?
- What role can NMAs play in a competitive market for the delivery of goods and services which can no longer be considered as part of the natural monopoly? In other words, how can an NMA compete fairly in the market for these products and services?
- What institutional/regulatory environment can be created in which the motivation and rewards exist for management and staff to be responsive in a dynamic technological and developing client environment and in furthering society's interests in the broadest possible use of government owned geospatial data?

- 5-2 What constitutes the present Natural Monopoly of NMAs?

The geospatial data business can be divided into the preparation of the foundation data sets for all other public and private thematic applications as a common spatial reference for end-

users and for value –adding users. End-users take the foundation data and add atttribute values or other thematic data for their own purposes. Value adding users do the same for re-sale to third parties. In a networked digital geospatial data environment, the consistent availability of up to date and reliable foundation data opens opportunities for a broad sharing of this foundation data set with significant positive externalities to society. In addition, it facilitates participation in the information market place by all thematic geospatial data owners who apply the FD and who thus become part of the information economy. This environment is called Geospatial Data Infrastructure (GDI).

NMAs have been responsible for the production of the foundation data in hard copy form for up to 200 years and sometimes more in some countries. Before the introduction of ICT, the production processes were analogue and the output was in hard copy, highly standardised topographic maps serving a multiplicity of users with one product as shown diagrammatically in Fig. 2a. This was the old natural monopoly.

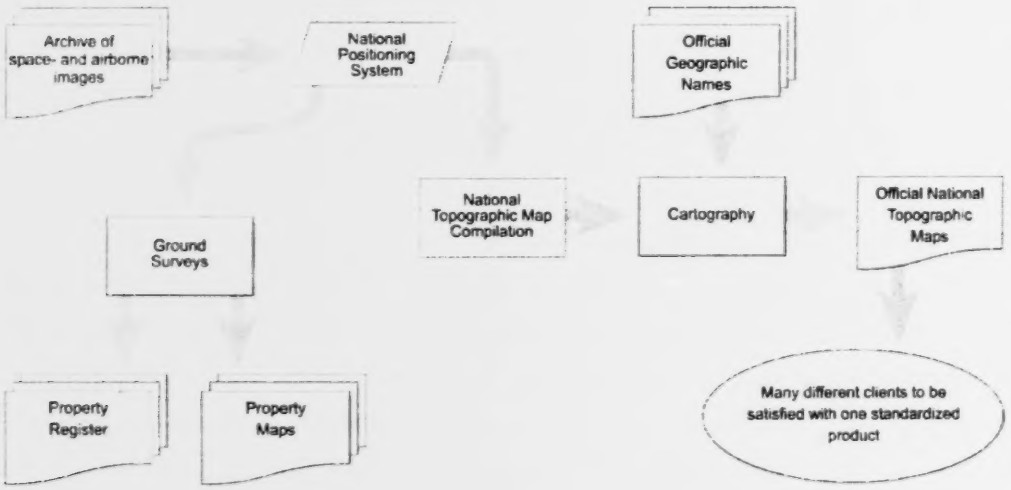


Fig. 2a: The conventional natural monopoly of NMAs .

Ubiquitous availability of digital technology has changed the business environment significantly as indicated in Fig. 2b. The source of the foundation data is also satellite and airborne imagery which, combined with the national positioning system, produces the national elevation model. To the elevation model can be added the basics of the topography to produce a so-called Topographic Template, Smith and Rhind (1999), which, properly structured, serves as a geospatial reference for thematic applications. Not all foundation data can be seen from the imagery. Official geographic names or property boundaries require ground surveys or administrative methods for their collection. The foundation data can be seen as an interrelated system, which we shall call the National Foundation Data System (NFDS). In response to the new demands for product diversity the constituent parts can also be marketed separately or in combinations.

For the purpose of this paper, the market for the NFDS has been divided (Fig. 2b) into two segments. The first segment is for analogue, special purpose maps produced on demand (but using digital methods). Note however that these maps can also be delivered in an internet environment. The second segment is of growing importance, namely the market for digital data for the Geographic Information System community. In each market the foundation data being combined with thematic data for end users or for value-added processes and products in a competitive market for a host of geospatial data applications and systems.

In this concept national topographic maps become value-added products, i.e., attribute values relevant to the content and symbology of official topographic maps are added to the topographic template. Entry into the value-added market for both market segments, including, for example, the production of national topographic map series requires relatively little capital and is not necessarily any longer part of the traditional natural monopoly of the NMAs. In fact it is expected that there will be a growing market in this field, with companies competing to meet the demand for growing product diversity when access to government owned data becomes easier. In part this also reflects the political vision presented at the start of this paper.

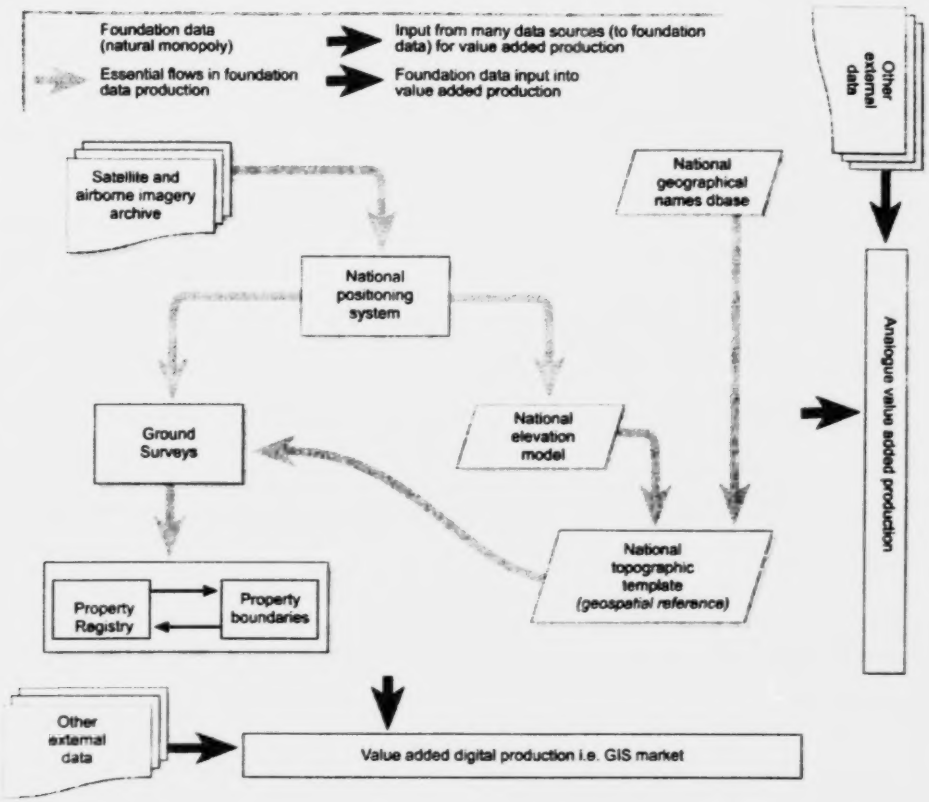
Foundation data (natural monopoly)
Input from many data sources (to foundation data) for value added production
Essential flows in foundation data production
Foundation data input into value added production
Other external data
Satellite and airborne imagery archive
National geographical names dbase
National positioning system
Analogue value added production
Ground Surveys
National elevation model
National topographic template (geospatial reference)
Property Registry
Property boundaries
Other external data
Value added digital production i.e. GIS market

Fig. 2b: The modern natural monopoly of NMAs

5-3 The National Foundation Data System (NFDS) as natural monopoly

In economics an industry is said to be a natural monopoly (NM) if a single firm can produce its vector of outputs more cheaply than any multiplicity of enterprises. The NFDS must cover the country as a whole to be of use to government. Hence, the 'relevant market' is the demand for foundation data of the country as a whole. The NFDS also has the characteristics of an imperfect public good, Coopers and Lybrand (1996) Characteristically, the sunk costs in the NFDS are many orders of magnitude larger than the cost of dissemination. Competitive entry into the NFDS business is therefore difficult and could, in fact, lead to duplication of the NFDS, which makes no economic sense whatsoever. Hence, the sunk cost *and* scale economies together deter entry into the NFDS market by other firms. Therefore of the NMAs outputs, the individual elements of the NFDS and combinations thereof qualify as a natural monopoly. Important is, however, that relatively low-cost, ubiquitous electronic surveying

Basically no monopolist is allowed to take unfair advantage of its monopoly power. This is in many countries also regulated by various forms of Anti Trust Legislation. Government information agencies are also forbidden to participate in the competitive market on the basis of cross subsidies from their government monopoly activities.

All things considered these are valuable but not complete arguments because they overlook the role of *economies of scope*. We stated earlier that the sunk cost *and* scale economies together deter entry into the NFDS market by other firms and that this leads to the NFDS being a natural monopoly. The natural monopoly position offers economies of scale in the operation especially if large scale topographic framework and property boundary data production can be combined in the NFDS, as indicated in the model shown in Fig. 2b.

If, as a result of the economies of scale of a natural monopoly, it is more efficient to produce product x and product y together in the monopolist's facilities instead of separately in different companies, society benefits from these economies, called *economies of scope*. Given the specialised know- how and capacity in an NMA due to its natural monopoly position, we should expect it to be a successful competitor, although this is by no means assured.

Mathematically this can be represented as follows:

It is in the interest of society if

$C(x;y) < C(x;0) + C(0;y)$ where $C(x;y)$ equals the cost of producing product x and product y in the same facility; while $C(x;0)$ and $C(0;y)$ are the costs of producing them in separate facilities.

$$C(x;y) - C(x;0) < C(0;y)$$

Or:

$$Ic(y) < SAC(y), \qquad (1)$$

Where Ic(y) equals the incremental cost of producing product y in addition to x in the monopolist facility and SAC(y) is the stand alone short run average cost of producing product y by itself.

Hence (1) states that the incremental cost of producing product y in the monopoly is smaller than the stand-alone cost of producing product y. These net gains to society are *economies of scope*.

Let product x be the foundation data which are necessary input for the production of value-added product y. A problem of unfair competition arises when firms compete with the NMA for the production of y for which they need the foundation data x owned by the NMA. Unless prevented from doing so the NMA will take advantage of its monopoly and charge itself less for the use of x than it charges the competition and thus compete unfairly with a lower price. If the NMA could be prevented from abuse of its monopoly, and a fair and competitive environment in the value-added (non-monopoly) part of the business could be created, the market forces, as a clear and uncontestable mechanism, will determine if (1) holds and thus if economies of scope are being realized.

This is called providing a level playing field for all competitors in the value-added business. That is, equal access to the assets of the monopolist (NMA) needed by competitors to function in the market place if the NMA is one of the competitors.

6-2 How to provide a level playing field?

Providing a level playing field is a problem of access to an asset controlled by a monopolist from which he may not derive unfair advantage, as this would distort competition. This is not an unusual issue in monopolistic situations, for example, consider competing railway companies who must use a railway bridge that is owned by one of them. In economics this is called the problem of 'bottleneck pricing'.

If the NMA were not also a supplier of value-added products in the competitive market, charging one price for the foundation data to all value-added producers that compete with one another would not constitute a competitive impediment. By avoiding differential pricing in the sale of bottleneck products or services to final product providers, they are left free to compete for customers strictly on the merits.

Society will only benefit from economies of scope if the NMA that sells the bottleneck product is also a seller of value-added products, provided equal access to all competitors including the NMA to the NFDS (the bottleneck product) can be assured.

Baumol *et al* (1997) provides the theoretical basis for dealing with this issue. This principle is called the "Parity-principle formula for bottleneck-service pricing". As applied to the NMA it would mean the following:

The minimum price P of the final(value added) product of competitor K equals the price of the bottleneck product (foundation data) P(b) *plus* the incremental cost Ic(K) of the value adding activity:

$$\text{Minimum } P(\text{final product},K) = Pb + Ic(K) \qquad (2)$$

In the case of a level playing field, the minimum price P of the final (value added) product of competitor K is equal to the price of the final value added product charged by the monopolist N *minus* the incremental cost Ic(N) of the value adding activity by the monopolist N *plus* the incremental cost Ic(K) of the value adding activity of competitor K:

$$\text{Minimum } P(\text{final product},K) = P(\text{final product}, N) - Ic(N) + Ic(K) \qquad (3)$$

(this equation defines the level playing field).

Solving (2) and (3) for Pb gives:

$$Pb = P(\text{final product } N) - Ic(N) \qquad (4)$$

where K = competitor
N = NMA (bottleneck producer, i.e. foundation data owner)
Pb = price of bottleneck product (NFDS)
Ic(K) = incremental cost of the value adding activity for the competitor K
Ic(N) = ditto for the NMA.

(4) States that a level playing field is provided if and only if the price for the foundation data charged to the competitor K is the same as the price, which the NMA charges itself. Of course the NMA, as a monopolist, will not do so out of its own volition. Therefore an independent regulator needs to oversee that this principle is being adhered to.

Sections 5.1 and 5.2 provide the conditions under which economies of scope can be realised by allowing the NMA to compete in the value added open market. For the next part of the argumentation about the requirements of economic efficiency in the pricing and distribution of National Survey materials it will be necessary to make some assumptions about government policy.

6-3 What should be a consistent price setting behaviour of the NMA on the NFDS?

We shall assume that government has three strategic goals:

i- For its own purposes and efficiency it must have guaranteed access to the NFDS at *the lowest possible cost;*

ii- In the interest of society government should also pursue the broadest possible use of the foundation data because this would multiply the *positive externalities* mentioned earlier and avoid the inefficiencies to society arising from the use of inferior substitutes which do not meet the minimum standards and specifications of reliable foundation data;

iii- In the context of reducing deficits and following the *"user pay principle"* governments will demand that the NFDS become independent of government subsidies within a reasonable time, say 5 years.

*These strategic goals imply a strategic objective for the management of the NMA, namely that of maximising output subject to the constraint that economic profit cannot become negative.*

In other words: to ensure the broadest possible use of the NFDS the price should be as low as possible but not so low that it requires continued government subsidy. Against this background we should have another look at pricing and market segmentation.

Figure 3 demonstrates the difference in pricing under the constraint of profit-maximising and output-maximising. The condition for profit maximising is that the long-run marginal cost (LMC) equals the marginal revenue (MR). Hence, with a given technology a monopolist

would produce the quantity Q* for which the LMC is equal to MR. For that quantity, the demand curve indicates the price P*. Profit is indicated by the shaded area Π. The output-maximising manager will set production at the point where the demand curve (D) intersects the long run average cost curve (LAC), that is at Q′ for which a price P′ is indicated. Clearly profit is zero but output is raised by the lower sales price caused by scale economies benefiting customers. Shareholders in this company would lose Π. If government is the sole shareholder, as in the case of an NMA it may be willing to forego these profits in favour of providing lower cost access to the foundation data, and achieving the positive externalities generated by broader use of the foundation data. *At the point (P′,Q′) profit is zero. Hence, if government wants to ensure full cost recovery it must stipulate prices where economic profit may not be negative.*

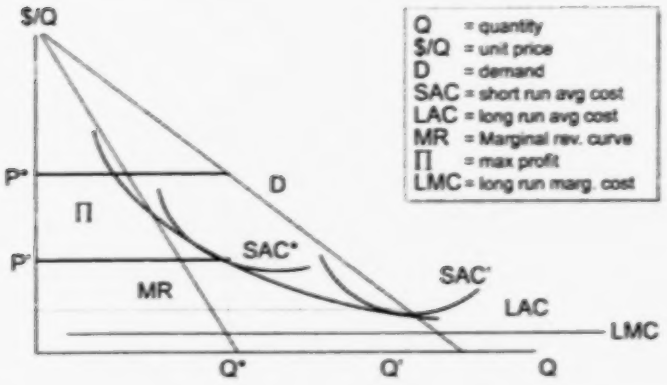


Fig. 3: Profit maximizing vis a vis output maximizing monopolists

6-4 Management discipline in defining the content of the NFDS.

Even at the price P′ the NFDS products may be so expensive that large parts of the potential client community would turn to cheaper and non standardised substitute products and thus prevent some of the positive externalities.

P′ is a function of the LAC. This, in turn, is a function of the complexity of the NFDS products such as the Topographic Template. The more complex, the higher the LAC and the higher P'. To prevent government from having to resort to subsidies to bring the price down and thus increase demand and so increase the positive externalities it should hold management to the objective of zero subsidy to be achieved over for example a five year period. This will force management to reconsider the content and complexity of the NFDS with a view of finding a balance of cost and product complexity in response to the broadest possible market.

It appears to be very difficult for NMAs to see the Topographic Template as a more simplified and specialised product than the digital copy of a topographic map. The latter is in almost all cases too complex and takes too long to produce and subsequently maintain to serve as a consistent spatial reference for most GIS users. See, for example, Department of the Environment (1987, p. 67).

Hence the economic constraint on the monopoly pricing combined with a "no subsidy in five years " policy provides management with:

- The discipline to critically review the content definition of the NFDS and guard against the addition of data which are not essential to the effectiveness of the NFDS, and
- The motivation to innovate and apply the most efficient combination of technologies and work processes to achieve the highest levels of efficiency possible.

Unfortunately, in many NMAs this discipline does not exist as the conventional topographic map content in digital form is assumed to meet the requirement of the new user community. Also the tendency exists to uncritically add new data content without real hard demand justification, thus adding to the difficulty of meeting the requirements of timeliness of production and maintenance as well as lower prices. Finally, for routine government

organisations it is very difficult to realize the motivation to be innovative and efficient due to a lack of relevant (to the market) benchmarks and due to the complexity of implementing associated reward systems for management as well as staff.

6-5 Other price setting behaviour and cross subsidies

We have suggested earlier that the market can be split into end users of individual elements of the NFDS or combinations thereof (users who apply the foundation data for their end use) and value-adding users (clients who take the foundation data and add other data to create new products, either directly for single clients or for sale in a broader market) (figure 2b).

Let us suppose that the NMA does not participate in the value-adding market. Then it would stand to reason that it charges the price P′ (fig. 3) for the elements of the NFDS. This policy would lower the prices of value-added products and services and generally have the desirable effect of stimulating the geospatial data production industry, which would be in line with contributing to meeting the high expectations of the benefits of the information society.

As we have shown above, from an economics point of view the NMA should be allowed to participate in the value-adding market if a level playing field can be guaranteed for all competitors. The condition for this is that the NMA only be allowed to charge its competitors the price for the NFDS it charges itself. For the reasons explained in the former paragraph this is the price P′.

The competitive segment of the market will determine whether economies of scope can be extracted. Although the NMA is expected to be a successful competitor, this is by no means guaranteed. In its zeal for budget reductions, government may be tempted to cross-subsidise the NFDS from the commercial activities, for example , by providing unnecessary data to the NFDS. In light of the inherent uncertainties in the competitive segment of the market this should be prevented. The NFDS must stand on its own financially, either on the basis of total cost recovery or be partly subsidised. Cross subsidy also detracts from the management discipline required to meet all 3 strategic goals mentioned in Section 5.3.

What happens to the profits from the value-added market? These should be re-invested into the enterprise to improve its efficiency. Undoubtedly some will see this as an indirect cross-subsidy to the NFDS, but we do not accept this argument. If it is in society's interest to

extract economies of scope, it follows that it is also in its interest that this is done as efficiently as possible. Reinvestment of profits from the value-added segment of the market to improve efficiency in the NFDS production environment may help realise the positive effect of economies of scope. Cross subsidy on the other hand would imply higher than necessary output or uncritically increasing data complexity.

It would be easiest to administer one price (P') for the NFDS products for all users. However, NMAs will be tempted to practise price discrimination for end-users of combinations of the NFDS elements. For institutional users, price elasticity of demand is often high. They need quality data and within bounds they will pay for it. In part this is due to the fact that relative to the financial implications of the activities for which the data are needed, the cost of the data is low. Willingness to pay can be discerned in negotiations, and in most cases a deal can be struck, for example, for issuing subscriptions to updated NFDS products, as opposed to one time sales. It would require very careful analysis of the market segments and their relative financial importance to say in how far this price discrimination would conflict with output optimisation, necessary to meet the goal of achieving the broadest possible use of the NFDS.

6-6 The role of regulation

Natural monopolies need regulation in order to ensure that they do not exploit their market power, for example by setting monopolist prices. Much has been said and written about this subject, more recently addressing the degree of overkill and the high costs of regulation. See, for example, Posner (1969) for an extensive critique of regulatory practice, or Train (1991) or Baumol and Sidak (1994) all of whom incorporate much international experience of standard regulatory mechanisms. Baumol *et al (1997)* provide a sort of bottom line for regulatory involvement as explained earlier which appears to be applicable to NMAs.

They present the principles of 'the new approach' to economic regulation. "The sole purpose of economic regulation is to facilitate and encourage effective competition where feasible, and to provide an effective substitute for competition where that is not possible, at least for a substantial period. The underlying premise of the new regulation is that where competition is effective it can do a better job of protecting and promoting the public interest than any government agency. Therefore where, and only where, competition is either absent or too

feeble to do the job, it is appropriate for the regulator to step in. But in doing so, the regulator's obligation is severely limited. It is to supply as near a substitute for the missing ingredient as can be devised, that is, to determine means to elicit the business behaviour that effective competition would have enforced if only it had been present."

In regulation of the NMA monopoly one must keep in mind the 3 strategic goals of government. It appears then that the lowest level of independent regulation must focus on:
- the level playing field.
- desirable pricing behaviour (based on output-optimisation) of the NMA;
- the ban on cross–subsidising the NFDS from the commercial value-adding activities;

As long as NMAs continue to be a standard part of the public service there are many impediments which make it next to impossible to carry out such regulation, not the least of which is the absence of complete cost-accounting systems in most government organisations. Another issue is the preferential position of government organisations with respect to the tax system.

We can now address the final question of Section 2: *What institutional environment can be created in which the motivation and rewards exist for management and staff to be efficiently responsive to the changing client environment and in furthering society's interests in the broadest possible use of government owned data?*

**7- Points of departure and principles for the privatisation discussion.**

In order to meet the three strategic goals of Government (Section 5.3) with economic efficiency, the following points of departure and principles will form the management framework for the NMAs:

1- For the NFDS segment of the market the NMA is a natural monopoly. Due to the government's objective of having the broadest possible use of the NFDS and thus increase positive externalities in society, the NMA operates as an output maximising monopolist,

2- The consequence of this is that the price for NFDS products must be equal to the long run average cost at a point where economic profit is not negative,

3- For society to benefit from the economies of scale and economies of scope, the NMA must be allowed to compete in the value-added market segment. This will be on condition that the parity-principle formula for bottleneck-service pricing is applied. Following this principle, the NMA would charge itself and competitors the price mentioned under 2, subject to regulatory supervision.

4- The NMA must be constituted under corporate law, with accounting and financial reporting requirements enforced. This will permit calculation of relevant costs. The legal and taxation rules must apply in just the same way as for the private sector.

5- As it is uncertain whether the NMA will compete successfully in the value-added segment of the market, society's interest demands that there be no cross-subsidy from that market to the NFDS.

6- The NMA may practise price differentiation in the end user market for combinations of elements in the NFDS.

7- Management of the NMA will be given (for example) five years to make the agency financially self-sufficient and cease being a charge on the taxpayer. To this end, it must a balance complexity of content of the NFDS and long run average cost (and, thus, price), in such a way that output is maximised. This will be the motivator for management to implement the necessary procedures with the client community to rationalise the content of the NFDS.

8- Management and staff incentive plans must be designed to promote this objective.

9- The NMA's independent regulator must be given the tools needed to:

a) oversee the implementation of the 'level playing field',

b) ensure that there are no cross-subsidies from the value-added competitive segment of the market to the NFDS,

c) ensure that pricing is in sympathy with the requirement for output maximisation, subject to the constraint of zero subsidy to be achieved in a defined and accepted time limit.

10- Profits from successful competition in the value-added segment of the market may be re-invested in the agency to improve its efficiency.

*We have now stated the principles and points of departure, which define an effective business environment for the NMA in meeting the three strategic goals of Government. We have already observed that it is impossible to meet these goals under the normal regulatory*

*environment of Public Service. It is at this point and only at this point that discussion on privatisation or reduced ties to public service regulation has a rational context of principles.*

**8- Regulatory Reform and the future performance of NMAs.**

Any form of increased independence from public service regulations must serve the principles and points of departure presented as prerequisites of the strategic goals of government with a well functioning NMA.

Outright privatisation of National Surveys is folly. It would place the ownership of all data assets in private hands, including the exclusive right to exploit these. Governments would thus lose complete control over strategic information assets to which they need unlimited access to govern.

It is also highly questionable whether any private enterprise would entertain a serious bid for an NMA if the requirement is that it act as an output maximising rather than a profit maximising monopolist and have no exclusive right to exploitation of the monopoly.

Furthermore, there are many uncertainties caused by the lack of commercially relevant and reliable management information about most NMAs to assess viability in the new regulatory setting. Potentially interested companies would hesitate to bid on a franchise, license, or concession, and would expect governments to pay a large risk premium.

The critical questions are really :
-What does government want to achieve with the NMA?
-What is the best regulatory environment for this?
-What price is it prepared to pay?

There are choices for solutions such as issuing a management contract, tendering for concessions or franchises, or establishment a special agency status whereby political accountability for the performance remains with a Minister of Cabinet. In different institutional environments and countries the answers may be different in finding an adequate

solution for reinventing the regulatory environment for he NMA. But in all cases the three basic questions cited here must be adequately answered.

In a number of countries some form of special agency has been developed successfully. For example, the Netherlands' Cadastre, Service New Brunswick (SNB), the Ordnance Survey of Great Britain (OS), the Danish National Survey, the NMA of New Zealand, and there may be others. Service New Brunswick and the OS were given about five years to put their houses in order and become self-sufficient or almost so. Similar targets were given to the others. In all those cases political accountability for the performance of the NMA has always remained with a Minister of Cabinet. Those organisations that have large scale and property data in their NFDS seem to have a greater chance of achieving 'independence' and self-sufficiency than those that do not.

The extent to which these agencies have followed the rather rigorous model proposed is not known. For example, little to nothing is known about (the logic of) their price setting mechanisms and their accounting systems. It will certainly be worthwhile to test the model against these real world examples and report the findings publicly.

In the author's view any solution that meets the proposed principles and points of departure will meet the requirements of efficiency in the pricing and distribution of National Survey materials. It will furthermore create the positive and motivating management environment NMAs need to fulfil their modern mandates.

## 9- Epilogue

The analysis of the economic efficiency of pricing and dissemination of national survey products and services was constrained by the three strategic goals or policies of the national government. In most industrial countries these are reasonably well-accepted government policies. But what if government decides to continue subsidization of the NFDS and give away the data to government departments and the public for nothing or next to nothing? Or if it decides to do so for government departments but in addition severely restrict the free dissemination of the NFDS to the public? Or if it decides to give the NMA an uncontrolled monopoly to operate in the value added market? In each instance a economic price will have to be paid. Particularly the creation of the management discipline that motivates management

of the NMA to be efficient and responsive tot the market may suffer. Governments need to decide if they want to pay that price. Also in the setting of prices governments may decide not to be as consistent as has been suggested. For a discussion on pricing issues see for example Rhind (2000). Furthermore the backdrop of the stage on which the performance of NMAs is played out is continuously changing.

Technology gallops forward and novel private sector capabilities will emerge that can provide a fully integrated geospatial data service at high accuracy, which is expected to even satisfy some municipal level applications. When such services do become available and are proven reliable, consistent and affordable, the pressure will mount on government to justify its continuing involvement in national surveying production.

For example, there are currently three US consortia being created, each owning their own satellite with high resolution (1 m), remote sensing capacity, who claim to be able to provide data but also vertically integrated value-added services. The pricing structure for these services is still not known, but having three in the market would suggest some competition. We need sound principles upon which to judge the impacts of these developments on the extent of government services. In the absence of these principles the reaction will be one of improvisation, which could be to the detriment of the country and the public.

It is in the interests of government and of society as a whole that the future can best be dealt with from a position of strength of the NMA. The alternative is a position of incompetence and inefficiency, in which solutions are being enforced by powerful external forces which give no assurance of control over the performance of information that is of strategic importance to governments.

Another aspect of emerging technological opportunity lies in the linkages between the NMA and the provincial and municipal agencies which are responsible for the local Foundation Data Systems. These new technologies will offer opportunities for increasing efficiencies by automatically or semi-automatically deriving lower resolution data at the national level from higher resolution data which have been prepared at local levels. The development of these approaches will require co-ordination between those organisations which may be better motivated if they were to be more independent of government than they are now.

It would be imperative for NMAs to respond to these challenges out of a position of strength and with thorough scientific and engineering know-how while operating in a business like environment. Only then will new developments be perceived as new opportunities to meet the requirements of their mandates instead of as threats. All the more reason to proceed with innovative approaches to provide these organisations with the regulatory environment in which innovation and efficiency in serving new and as yet unpredictable markets can flourish under fair competition with the private sector.

There is no suggestion that the role of government needs to be exactly the same in every country. The government involvement in spatial data infrastructure development and the regulatory position of the associated government agencies depend on the culture in each country or jurisdiction. There are issues of copyright protection of government owned data in most countries which do not exist in the US. Similarly the protection of the privacy of individuals and companies is not dealt with in the same way in different countries. See, for example, Buchwald (1995). Yet, in spite of these differences, it seems logical that models such as the one we have proposed would assist the decision-making process in a practical way, leading in each case to appropriate local solutions.

Even though much emphasize has been placed on the need for approaching the future of NMAs out of a position of strength, the paramount question is always: How can a government's requirement for access to geospatial data of the country be met in the most reliable, effective and efficient way? This is a different approach than arguing from what NMAs are capable of or are being allowed to do, which is the more dominant way in bureaucracies. The proposed principles and points of departure are intended to at least provide a rational starting point for the discussion between policy makers and executives about the continuing relevance of National Mapping Agencies.

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**Appendix 1**

Resolution 6 of the 15 th UN Regional Cartographic Conference for Asia and the Pacific, Kuala Lumpur, 11- 14 April 2000.

Economic aspects of modern surveying, mapping, geospatial data infrastructure and land administration programmes

*The Conference,*

*Noting* that all modern surveying and mapping, geospatial data infrastructure and land administration projects must compete for scarce economic resources with other valuable projects,

*Recognizing* that many Governments seek to reduce the cost to the taxpayer for fundamental and infrastructural geospatial data services by various forms of privatization, cost recovery, outsourcing or revenue generating initiatives,

*Considering* that these initiatives have a significant technical, organizational and institutional impact on national surveying and mapping,

*Bearing in mind* that the expanding array of options for professionals in the mapping field imposes choiees in which economics plays a decisive rote both in government and in the private sector,

1 . *Recommends* that the United Nations Secretariat within available resources, and in cooperation with ether appropriate organizations and educational institutions, initiate an international workshop en economic aspects of modern surveying, mapping geospatial data infrastructure and land administration;

2. *Welcomes* the invitation of the Government of India to host the proposed workshop.

**APPENDIX 2**

## D. DRAFT REPORT

**UNITED NATIONS ECONOMIC COMMISSION FOR AFRICA- AD-HOC GROUP OF EXPERTS MEETING, 6- 10 NOVEMBER 2000, ADDIS ABABA, ETHIOPIA:**

**WORKING GROUP 4: ECONOMIC ASPECTS OF GEO-INFORMATION**

47. Participants:

- Jacob Gyamfi-Aidoo (chair)
- Liz Gavin (rapporteur)
- Dick Groot
- Pal Foyn Jespersen
- Helge Donnum

48. Two main points:

(c) Political and economic justification for investment by government in the collection and management of fundamental geo-information as component of National Information and Communication Infrastructure (NICI)

(d) Cost-efficient development, production and dissemination of geo-information

51. A shift in perspective:

(a) *from* focussing on the need for mapping and generation of spatial data,

*to* the use of information describing the country's assets and potential in terms of its geography,

*in order to* gain the attention of policy makers and potential local and foreign investors

(b) Knowledge of the geography of one's country is a necessary but not sufficient condition for good governance

(c) However, it is essential to government in order to allocate resources and provide services effectively and efficiently

(d) It is needed to attract investment e.g. mining companies will not make investments unless there is documented and accessible knowledge of the geology of the country available

(e) Wider dissemination of knowledge about one's country constitutes better marketing

52. More on knowledge:

(a) Unlike other assets, knowledge appreciates in value through use and depreciates in value through lack of use

(b) Knowledge cannot be lost through sharing

(c) New knowledge may be derived through integration of different set of geographic information from different sources

Question: Have any studies been made to estimate these benefits. What about the work of Kenneth Arrow on the contribution of knowledge to the economy?

53. The marketplace for geoinformation

(a) In a perfect market, supply and demand determine pricing

(b) Imperfections in the market lead to higher prices and hence not as wide a distribution of information and knowledge

(c) Identify supply (I.e. data producers) and demand (I.e. data users)

Question: Is it possible to quantify the inefficiencies due to market imperfection?

54. Suppliers ("data producers")

(a) Government: at national, provincial, local levels

(b) Private Sector – data, technology, knowledge transfer

(c) Donors, foreign government and business

(d) Suppliers of (high resolution) remotely sensed imagery

(e) NGOs

55. Suppliers ("data producers")

(a) Government (internal) at national, provincial and local levels

(b) External governments; donors

(c) Parastatals, utilities

(d) NGOs, CBOs

(e) Private companies

(f) national,

(g) foreign

(h) Private citizens

56. Role of government (1)

Foundation/framework data needed for building national infrastructure as part of NICI, to facilitate access, responsible use and integration at affordable costs: traditionally government co-ordinates and funds the development of national infrastructure

57. Role of government (2)

(a) The creation of "positive externalities" and the reduction of "transaction costs" (see 60, 61)?

(b) Transparency of access rules, pricing and conditions of use.

(c) Knowledge of competitive advantage needed for growth

(d) provide the motor for developing further information products and services.

Question: can externalities be quantified? Do estimates exist for the market of value added products and services?

58. Benefiting from donor participation

A possible problem:

— the effect of uncoordinated donor interventions may be to create an artificial demand or undermine economies of scale by duplicating supply

59. Recommendations concerning donor contribution

(a) The co-ordination of donor interventions is needed

(b) Donors should be encouraged to contribute to building foundation/framework data within the framework of national policy concerning the systematic building of information infrastructure (NICI plans)

(c) Data products emerging from donor-funded projects should be incorporated into the national information infrastructure

60. Transaction costs

*These are the costs associated with obtaining and using a product, apart from the actual price paid, e.g.*

*— cost of finding where to obtain information*

*— cost of turning the data obtained into a product which is fit for intended use*

61. Reducing transaction costs

(a) Making information more easily accessible, I.e. establishing a clearinghouse

(b) Reducing effort needed to ensure that the product is fit for use:

— setting standards for geographic information

— provision of metadata describing data quality, lineage etc.

(c) Providing complete information to potential investors

Question: Is it possible to estimate reduction in transaction costs?

62. Cost recovery ?

(c) Question 1:

— if a government is funding the gathering and management of foundation/framework data, should there be attempted cost recovery against demand from parties outside government?

(d) Question 2:

— if cost recovery is not attempted, even in the longer term, what mechanisms can be used to ensure that a data producer is producing products on public money for which there is a real demand?

63. Factors to consider with respect to embarking on cost recovery

(a) Higher costs leads to lower demand, i.e. the audience receiving knowledge which could drive further investment or the creation of information products and services is narrowed

(b) There are administrative costs associated with cost recovery

(c) There is little point to this exercise unless revenue returns to the agency bearing the cost of generating the information, the dissemination and the administration.

64. Framework data sets

*Def.: geographic data needed by more than one government agency for fulfilling its service delivery obligations*

— Cost effective to have this captured once for use by several government agencies, I.e. economy of scale

65. Re-engineering of production process by data producers (e.g. NMAs)

(a) Technology makes it possible to be able to create many different products, customized to the needs of individual demanders

(b) A "just-in-time" (JIT) philosophy can be adopted: I.e. products are produced on demand; don't stockpile - there is a cost associated with this

(c) Even if production is outsourced, capacity needs to be retained within the outsourcing institution (avoiding "asymmetric knowledge") which may cause inefficiencies.

Question: Are there any studies of the cost of asymmetric knowledge in transactions in the economics literature?

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United Nations E/CONF.93/BP.4

# Economic and Social Council

Distr.: Limited
14 December 2000

English only

**Seventh United Nations Regional Cartographic Conference for the Americas**

New York, 22-26 January 2001

Item 7 (b) of the provisional agenda*

**Reports on achievements in surveying, mapping and charting in addressing national, subregional, regional and global issues, including technical issues**

## Mapping, geodetic control, remote sensing and Geographic Information Systems in the Americas and worldwide, 2000

**Submitted by the Secretariat****

* E/CONF.93/1.

** Prepared for the Seventh United Nations Regional Cartographic Conference for the Americas by Professor A. J. Brandenberger, Faculty of Forestry and Geomatics, Laval University, Québec, Canada.

00-80452 (E) 100101

- General Introduction
- Status of the World's Graphical Topographic Mapping, Revision & Geodetic Control
- Status of Digital Cartography (Digital Terrain Models)
- Use of Remote Sensing Technologies for Global/and Regional Map Coverages
- Relation between National Cartography and Geomatics (Geographic Information & Spatial Data Systems)
- Future Cartography Requirements
- Economics of Cartographic Operations

Conclusions and Recommendations

**Abstract**

The author has been requested by the United Nations to prepare a background paper for the 7th UN Regional Cartographic Conference for the Americas'with special emphasis on the Americas. Since no special survey by the UN for the year 2000 was performed (Distribution of a pertinent questionnaire to the National Cartographic Agencies of all UN – member countries), the available information is rather limited. Nevertheless, and in this background paper some comments are presented on the subject and dealing with the following aspects: Graphical and Digital Cartography (Digital Terrain Models) and geodetic control, the role of Remote Sensing Technology, for global/national mapping, relations between "National Cartography" and "Geomatics" and "Spatial Data Systems", future cartographic requirements, economics of cartographic operations. It is concluded that presently the world's and the continental cartography operations progress too slowly and consequently affect unfavorably the economy of larger development programs. For this reason it appears and must be recommended that steps be undertaken to increase the world's and local cartography operations, which might require to accelerate the world's annual cartography expenditures (budgets) from the present 0.1% of global GNP to an essentially higher percentage.

## General Introduction

The United Nations perform 6-7 years periodic surveys on the status of world mapping. The results of these surveys are usually presented at the United Nations Regional Cartographic Conferences and are based on information received from questionnaires completed by the National Cartography Agencies of the UN-member countries. Consequently, it was the time for the UN to forward pertinent questionnaires to the National Cartographic Agencies which agencies would have returned completed questionnaires before the date of the present conference. However,this was not done due to lack or change of respective personnel at the UN although a number of cartography specialists had recommended to have presented at this conference the results of a pertinent survey for the year 2000 (Millenium survey). Therefore, many required data for the various UN member countries, year 2000, are unavailable. Nevertheless some incomplete, estimated or extrapolated data are presented in this background paper based on Sources 1) and 2). For this reason and because of missing data explains why the present background paper is essentially shorter than previous background papers.

## I Status of the World's Graphical Topographical Mapping, Revision & Geodetic Control

### 1.Graphical Topographic Mapping and Revision (incl. Aeronautical Charting)

As in previous UN surveys the following scale ranges (categories) are considered (Ref. 1):

| Range number | Category |
|---|---|
| I | 1:25,000 and larger scales |
| II | 1:50,000 |

| | |
|---|---|
| III | 1:100,000 |
| IV | 1:250,000 |

Because no UN survey data are available (completed questionnaires) for the year 2000 little information can be presented in the present background paper on progress rates of the 4 scale categories. The only approximate figure which can be given is for the category IV and the Americas: Category IV is practically completed or nearing completion (1:250,000 topo mapping for the Americas). The same applies for the status of map revision in this category.

Here some remarks must be made regarding the use of satellite imageries for topographic mapping. This concerns imageries from such satellites as, Landsat/Thematic Mapper, Radarsat, the american remote sensing satellite Ikonos etc. with image ground resolution of up to 1 m. Here the question arises to whether such imageries have appropriate inter-pretation possibilities. Prof. Petries from the U.K. reported on this problem (1996) and this by means of results obtained from the so-called "Africa Test". In this test certain satellite imageries were compared with imageries from SPOT and super-wide angle aerial photography cameras (MC and LFC). It was found that about 30% of the total required planimetric map features were not identifiable on most of the considered satellite images and would require expensive field completion for official topographic maps. By contrast, the percentage of required and identifiable planimetric features on the super-wide angle aerial photographies was much better, normally at the 90 to 95% level.

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1) Background paper, by A.J. Brandenberger, United Nations Regional Cartographic Conference for Asia and the Pacific, Beijing, May 9-18, 1994.
2) Laval University World Surveying & Mapping Data Bank, A.J. Brandenberger (Administrator), c/o Photogrammetry, Faculty of Forestry and Geomatics, Laval University, Quebec (Quebec), Canada G1K 7P4.

## 1. Geodetic Control

Topographic mapping requires the availability of a geodetic control network. At the present, it can be estimated that on the land area of the earth there are at least 4 million official horizontal geodetic control points and 4.5 million vertical control points, making densities of 1 point per 34 $km^2$ and 1 point per 30 $km^2$ .respectively. In many cases this geodetic control density is insufficient for larger scale topographic mapping and also for cadastral surveying and mapping, (S & M.).

Fortunately, this situation will be essentially improved by having now available new and much more efficient technologies such as the GPS (introduced by the U.S.A.) and a similar system, GLONASS, developed in Russia. Already now, GPS has become one of the most significant achievement in Geodetic Sciences with a major marketing potential for the GPS industry. This becomes evident even on the U.S. Government level (at a recent White House briefing, Vice President Al Gore stated that the US GPS is a technology developed by the U.S. Government that will explode the emerging GPS industry into an U.S. $ 8 billion industry within the next 4 years and will create 100,000 new high-tech jobs, primarily in California).

## II Status of Digital Cartography (Digital Terrain Models)

Photogrammetry is the most important procedure for producing topographic maps. In the early past this was mostly done by graphical photogrammetry. At a later stage digital photogrammetry was introduced (analytical plotters, digital terrain models). But still and around 1995, Prof. Toni Schenk, President of a Commission of ISPRS, stated that probably less than 10% of all photogrammetry products were produced by digital photogrammetry. Consequently, the question arises about the usefullness of graphical maps (paper maps) and purely digital products. This becomes obvious from a

recent statement of Mrs. Vanessa Lawrence, Director General of the British Ordnance Survey: "There's a long-term future for paper maps – and the great success of the new Explorer series demonstrates that there,s a real demand for them. People who try to write them off are the same people who are convinced that books are going to disappear because information can be downloaded into palm-top computers. I don't believe it".

By the way, and as far as digital Terrain Model Technology is concerned it should be noticed that by the presently used and rather primitive point by point methods (Raster and Vector Systems) only form lines can be produced which are of lower accuracy when compared with lines stereophotogrammetrically plotted (e.g. contour lines) and in most cases the resulting maps would not reach an accuracy satisfying the rather stringent accuracy specifications for official topographic mapping.

## III Use of Remote Sensing Technologies for Global and Regional Map Coverages

It is known that photogrammetry and remote sensing technology and professions are closely related because both use aerial photographs or satellite imageries. Because of this, and in many countries, the pertinent professional societies are called National Societies of Photogrammetry and Remote Sensing. Nevertheless there are some differences between both professions in as much as photogrammetrists have some fairly good experience in photointerpretation and remote sensing while remote sensing specialists in general do not have enough professional experience in photogrammetry and geodetic sciences (ex. cadastral surveying & mapping which requires good legal experience). On the other hand remote sensing technology developed very rapidly in recent years and the respective world market is estimated at US $15 billion. For this reason some agressive remote sensing specialists attempt to dominate the photogrammetrists. An examply is the U. K. where the Photogrammetry Society has been merged with the Remote Sensing Society and it was proposed that the merged ·ociety should be named "The Remote Sensing and Photogrammetric Society". This is wrong, because photogrammety still belongs to geodetic sciences, and also in view of the

fact that national geodetic control and national mapping are the responsibility of governmental and pertinent government departments.

## IV Relation between National Cartography and Geomatics (Geographic Information and Spatial Data Systems)

It is the responsibility of National and Local Governments to reach for each country or territory a cultural and economic level as high as possible. This also applies to National Cartography (incl. National Geodesy). Further, economic and technical assistance programs to development countries must be considered and this also in view of the increasing internationalization of economic and technical development operations. This means that world -and national information policy and technology play an increasingly important role. This was the reason for the creation of the term "Geomatics", which is of a wider range than the classic term "Surveying and Mapping", and includes "Geographic Information Systems, GIS", or "Spatial Data Systems".

## V Future Cartography Requirements

In the future cartography operations worldwide must be accelerated, and this for the following reasons (factors): for the first time the worlds urban population has reached the percentage of 50% of the world population, and also because of a boom in the world's Tourism Industry (According to OECD Tourism has become the biggest industry in the world. It offers jobs for 200 million people and contributes 11.7% to the global GNP. Almost 700 million tourist arrivals were expected for the year 2000 , and this number is estimated to grow to 15 billion by the year 2020). Consequently, both factors will require substantial acceleration of world, regional and national cartography operations and this particularly for the larger scales surveying and mapping sector.

## VI Economics of Cartographic Operations, [Surveying & Mapping (S & M)] Activity

The present world's "Surveying & Mapping Activity" is an operation which involves a manpower of approximately 1.9 million persons with annual expenditures in

the order of US $ 25 billion (approximately 0,1% of the world's GNP). The particularity of this operation is that it is in many cases the first phase of larger development programs or projets. Consequently a too slow S & M phase could cause program termination delays which capitalised could exceed in a short time the cost for the entire S & M phase. Indeed, it must be stated that in the past and presently the world's S & M phase is too slow and steps have to be undertaken to accelerate this operation. This not only applies to S & M in general but also in view of special requirements for the forestry industry (the world's forest cover still amounts to nearly 30% of the world's land area) and also in view of the world's energy crisis (energy industry; the proofen oil reserves presently amount to 1,030 billion barels, but the global annual oil consumption increased by 32%). Also the world's Hydrographic S & M operation must be accelerated with regards to the transport industry on the water and the fishery industry (the world's fishery production is worth more than US $ 83 billion per year). Here, Cadastral S & M plays a particular role, also in the Americas: in Latine-American countries properties are not protected by property rights, (properties make up 90% of family assets in rural areas and 50% in urban areas; in the U.S.A. the percentage is 40%). In these areas, cadastral S & M costs substantially less than 1% of the property value (a more precise percentage still remains to be determined).

## VII Conclusions and Recommendations

Starting a new Millenium, a number of cartographers have suggested that a survey of the status of world cartography be again made for the year 2000 or eventually the year 2001 and this by the United Nations. Unfortunately such a survey has not yet been done.

For this reason it is highly recommended that such a survey be done as soon as possible and that the United Nations forward a pertinent questionnaire on the status of national mapping to the chiefs of all National Cartography Agencies whose countries are member states of the United Nations.

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United Nations E/CONF.93/BP.5

Economic and Social Council

Distr.: Limited
14 December 2000

English only

**Seventh United Nations Regional Cartographic Conference for the Americas**
New York, 22-26 January 2001
Item 7 (b) of the provisional agenda*
**Reports on achievements in surveying, mapping and charting in addressing national, subregional, regional and global issues, including technical issues**

# Developments in the acquisition of spatial data from imagery

**Submitted by the International Society for Photogrammetry and Remote Sensing****

* E/CONF.93/1.

** Prepared by Professor John C. Trinder, University of New South Wales, Sydney, Australia, and President, International Society for Photogrammetry and Remote Sensing (ISPRS).

00-80455 (E) 100101

# DEVELOPMENTS IN THE ACQUISITION OF SPATIAL DATA FROM IMAGERY

**Em. Professor John C. Trinder**
**University of New South Wales**
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## SUMMARY

The International Society for Photogrammetry and Remote Sensing (ISPRS) is a non-governmental international organization, devoted to the development of international cooperation for the advancement of knowledge, research, development, education and training in the photogrammetry, remote sensing and spatial information sciences, their integration and applications, to contribute to the well-being of humanity and the sustainability of the environment.

ISPRS covers a broad range of topics dealing with the acquisition and processing of data from a variety of imaging systems for topographic mapping and data collection for Geographic Information Systems (GIS), and environmental mapping and monitoring. ISPRS has seen significant new trends in the development of technologies and methods for mapping. New technologies available for mapping and data collection for Geographic Information Systems (GIS) include new sources of digital image data from space and aircraft, as well as technologies for information extraction.

Space-borne image data acquisition includes a choice from the range of satellite image data, based on the resolution of the data. Resolution is usually defined in terms of spatial, spectral and temporal resolutions. Spatial resolution refers to the footprint of the data on the ground, usually expressed as meters. Spectral resolution refers to the extent of wavelengths that are discriminated by the sensor. Temporal resolution refers to the repeat cycle of the data acquisition, that is the time between consecutive satellite passes over the same area.

For mapping high spatial resolution image is the preferred choice, since it is required for the identification of details in the image required for mapping. Airborne systems available for data collection for mapping include film based systems and new digital camera systems. The film based systems are the currently available technologies, but new digital systems are being developed to replace film systems. In addition, new terrain laser scanners provide a rapid system for derivation of terrain elevations.

Output from mapping systems are now digital, either as line maps or orthophotos. With the increasing introduction of digital photogrammetric mapping systems, orthophotos are becoming a more commonly requested map product. The digital orthophoto has the advantage that it can be overlaid on digital GIS data.

These new technologies have the advantages that they will lead to more rapid data collection, but also new levels of technology transfer and personnel training will be required for developing countries to be able to tale advantage of them.

# DEVELOPMENTS IN THE ACQUISITION OF SPATIAL DATA FROM IMAGERY

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## INTRODUCTION

**The International Society for Photogrammetry and Remote Sensing (ISPRS)** is a non-governmental international organization, devoted to the development of international cooperation for the advancement of knowledge, research, development, education and training in the photogrammetry, remote sensing and spatial information sciences, their integration and applications, to contribute to the well-being of humanity and the sustainability of the environment.

**Photogrammetry and Remote Sensing** are defined as the art, science, and technology of obtaining reliable information from non-contact imaging and other sensor systems about the Earth and its environment, and other physical objects and processes through recording, measuring, analyzing and representation.

**Spatial Information Science** is the art, science, and technology of obtaining reliable spatial, spectral and temporal relationships between physical objects, and of processes for integration with other data for analysis, portrayal and representation, independently of scale.

ISPRS covers a broad range of topics dealing with the acquisition and processing of data from a variety of imaging systems for topographic mapping and data collection for Geographic Information Systems (GIS), and environmental mapping and monitoring. ISPRS has seen significant new trends in the development of technologies and methods for mapping. Output products from mapping systems are usually digital, thus enabling the processing of the data in GIS or similar digital mapping software. There is an increased level of automation in information extraction, especially for terrain elevation data and the derivation of digital orthophotos. The use of orthophotos has increased as a product for the mapping, replacing line mapping in many cases. There is a much broader range of image data now available for mapping purposes, especially the new series of satellite systems, and there will be further such systems developed in the future. In addition, the use of the data is much broader than for only topographic mapping. Preservation of the environment

and supporting the sustainability of development are important applications of the digital data collected by members of ISPRS. Indeed, the sustainability of development is becoming a critical issue for application of image data, but ISPRS members are still to learn a great deal about how the technologies will be used for supporting sustainable development. This is an important issue for the future and should also be addressed by the UN.

This paper will summarize, under the topic of 'Spatial Data Collection Issues', the data available for mapping and the technologies use for production of digital map data.

## CHOICE OF IMAGE DATA

### Satellite Data

The choice of the most suitable image data from which to derive mapping and GIS will be a function of the applications of the map data. Because one set of image data cannot satisfy the production of all types of map products, the initial decision on choice of data must be based on the required resolution of the output product. Resolution is usually defined in terms of spatial, spectral and temporal resolutions. Spatial resolution refers to the footprint of the data on the ground, usually expressed in meters. Spectral resolution refers to the extent of wavelengths that are discriminated by the sensor. These systems may vary between broad ranges of the spectrum, as has been the case with most so-called 'multi-spectral' sensors, to very narrow bands of the spectrum, as is currently the case with the 'hyperspectral' systems. Temporal resolution refers to the repeat cycle of the data acquisition, that is the time between consecutive satellite passes over the same area.

- *High spatial resolution data*, better than 30 meters, usually involves large volumes of data taken with low repeat cycles, of the order of 20-30 days, as is the case with the remote sensing satellite, such as Landsat, SPOT etc. This poor repeat cycle can largely been overcome by providing pointing capability in the satellite, as is he case with recently launched satellites. In this case the repeat cycle will be as little as a few days, subject to weather conditions.

- *High spectral resolution data* will normally be acquired on low repeat cycles and comprise multi-spectral data ranging from a small numbers of bands to many hundreds as is the case of hyperspectral systems. Hyperspectral data sensing has opened up new areas of applications, which would enhance the use of remote sensing data, such as the discrimination of different

vegetation species, mineral types, diseases etc. It is therefore particularly useful for environmental mapping. However, for multi-spectral data, the repeat cycle will become an issue if changes in disease patterns of crop growth patterns occur more frequently than the repeat cycle.

- *High temporal data* is collected at very regular intervals, eg several times per day, as is the case with the NOAA satellites, but with low spatial resolutions of 1 to 4 km.

For mapping applications, the high spatial resolution data is chosen, since it is required for the identification of details in the image required for mapping. For high spatial resolution data, the repeat cycle is not usually an important issue unless there are rapid changes in details on the terrain surface.

Developments in low cost satellite systems, so-called micro-satellites, by a range of countries have enabled countries that do not have the funding or technologies to launch their own satellite systems to enter the space industry. Typical of these are the systems that have been launched by Surrey University in the UK, and others. The type of sensor that is launched by a country should be designed to suit the applications of that country and not simply to replicate systems being launched by other countries. Therefore, the decision to develop any satellite system should be based thorough investigations of the needs of the country and resources available to undertake such a project.

**High Spatial Resolution Satellite Systems.**

The applications of satellite data for mapping and GIS have so far been limited to small and medium scale mapping, usually for smaller scales than 1:25,000. However, the authorization for commercial ownership and operation of satellites giving 1 meter data has stimulated a number of companies to develop high-resolution earth observation systems. The first of these, IKONOS II launched by Space Imaging Corporation, which has been successfully operating for more than one year, is the beginning of a new era of satellite imagery wherein spatial resolutions match the resolutions of aerial photographic data. It includes a flexible imaging system for the acquisition of 1 meter resolution stereo-data, and 4 meter multi-spectral data. The suitability of this data for mapping is still being tested, but some initial tests indicate that the geometric accuracies of this data are beyond initial expectations. The applications of the multi-spectral data have not been fully explored, but it will clearly be of advantage for automatic procedures of information extraction. Company estimates are

that the imagery will be suitable for image mapping at scales larger than 1:10,000, indeed up to 1:2,400. However, this industry is in its infancy and therefore there are a number of issues that are unresolved in respect of the use of the data for mapping. At the time of writing this paper, only one successful launch of a high resolution sensor has been possible from three attempts. As well, since the systems are based on commercial ventures, the pricing of the data is based on a cost-recovery regime. The data is therefore relatively expensive and may not be affordable by developing countries.

Studies carried out to test the suitability of the data show that it should be suitable for mapping of peri-urban regions of cities as well as less densely populated areas, rather than inner city areas. It is likely that many countries will continue to base their mapping on aerial photography rather than the high resolution satellite data, since it has the flexibility of choice of scale to suit the purposes of the mapping project, time of photography, weather conditions etc.

A further issue is that the complete geometric characteristics of the image acquisition system, referred to as the geometric model of the data, will not be made available to the data users by the Space Imaging. This has the potential to affect the ultimate accuracy of information derived from the data, but the influences of these effects will depend of the purposes for which the data is to be used. To achieve the maximum accuracy from the data, it is believed that the geometric model will be required.

**Airborne Systems**

Film camera based systems will continue to be a major source of image data for mapping. However, aerial film camera systems have advanced significantly over recent years, especially in respect of the determination of camera exterior orientations. With the installation of both GPS and IMU on the camera, camera tilts and positions can me determined during flight. This has substantially reduced the need for field located ground control points, and hence significantly improved the economy of topographic mapping.

In parallel with the development of satellite systems, is the development of digital airborne systems. The ultimate intention is to replace the existing film based systems with digital systems. The advantage of the digital systems is that the data acquired is more flexible than that acquired by film based systems, and will be directly usable in digital photogrammetric systems. These systems will be available in 2001, but their cost is likely to be high until the development costs can be written off. It

is therefore clear that the data used for topographic mapping will involve film based systems, digitized by film scanning systems and used in the new generation digital photogrammetric plotters.

## SENSORS FOR ELEVATION DETERMINATION

Environment monitoring and assessment will increasingly require elevations as a component for analysis in GIS. The accuracy of the elevations will also impact on the quality of this analysis. Over recent years, greater accuracy elevation information has been requested for environmental assessment and monitoring, especially in environmentally sensitive and flat areas. In the past, derivation of elevations has been an expensive process, since it has involved a manual operation. There are number of new developments that are now available for rapid determination of elevation, based both on aerial and satellite systems.

The traditional photogrammetric optical approach has now been replaced by the digital photogrammetric systems, which enable the acquisition of elevations automatically by image processing, called 'image matching'. This system is rapid and accurate, provided the terrain is not covered by dense vegetation. Usually assistance from an operator is required to correct the erroneous elevations. The process does require a significant level of training for the users to be efficient in the use if these systems.

### Satellite Systems

New optical sensors dedicated to elevation extraction using fixed forward and aft camera systems, such as the high resolution systems described above, enable the acquisition of overlapping images that are available for the determination of elevations. Elevations can be determined from these systems with accuracies of 2 meters and better.

Interferometric SAR opens up new possibilities for global determination of digital elevation models from existing SAR data or from new missions. For interferometric SAR, the system involves the emission of radar data from one antenna and the acquisition of the reflected data on two antennas, or the system can also be based on the two separate passes of the satellite on two separate days, as is the

case with the ERS1/2 tandem mission. The Shuttle Radar Topographic Mission (SRTM) in February 2000 acquired data that will led to the determination of elevation over the Earth's surface from -54° to 60° in 9 days, with 30 meters spacing and accuracy approximately 10 meters. This data may be an important data set for the future for developing countries, although the processing will take 2 years to complete.

**Airborne Systems**

While some organizations will continue to extract elevation from aerial photography using optical instruments, the recently developed technologies for the automatic extraction of elevation from overlapping aerial photographs will become a major source of elevation data for mapping in future. It is expected that improvements will occur in the software design to overcome difficulties of extracting elevations over areas covered by trees and buildings.

Terrain laser scan systems is a recently developed technology that has now reached an operational stage. These systems involve a laser mounted in an aircraft that scans the terrain at right angles to the direction of flight. Measurement of the time take to receive the reflected signal from the terrain will enable the determination of high precision elevations. The system is a rapid terrain mapping that also penetrates thick vegetation. Hence it is a very efficient system for mapping, but requires large areas to ensure that it is economical. A number of systems are now on the market for terrain laser scanning and, while expensive to deploy, can lead to very economical mapping for large areas.

Multisensor data acquisition systems, such as camera and laser scanning are increasingly being used and require modification/extension of existing algorithms and procedures to effectively merge (fuse) multisensor data. At the same time, multispectral and even hyperspectral data have become available for other applications than traditional remote sensing, for example mapping urban areas. This greatly facilitates the automatic recognition and extraction of objects, such as buildings and roads.

## MAPPING METHODS

For medium and large scale mapping photogrammetric equipment has now reached the digital instrumentation stage. The analytical plotter technology that existed in the 1970s and 1980s is now being replaced by the digital photogrammetric systems. While it can be expected that analytical

optical plotter systems will be available for some time, most of these systems are likely to be replaced by digital systems within 10 years. This has an impact on developing countries, since training in the use of the new technologies will be required before they can be efficiently implemented. Since the normal product derived from the digital photogrammetric systems is an ortho-image, an image with corrected geometry, there is a change in trends in the preferred mapping product, from line maps to ortho-images. The advantage of the image map is that it contains the full features of the original image, and hence is an important layer for a GIS.

An important development in digital data acquisition is the ability to fusion of data to produce useful information by processing within photogrammetric digital systems and integration into GIS. This involved several focal points, which included algorithms for feature extraction which could be incorporated in systems for automatic registration and data fusion. Semi automatic procedures are currently found in commercial systems to speed up the information extraction process, but increasing levels of automation will be used in these systems in future.

With the need to interchange data between software and hardware systems, there is a substantial need for transfer standards for both image and vector data. ISPRS is working with ISO and OGC to develop appropriate standards. They will be important for any organization that is using digital data for the mapping and GIS. Training will be an important issue to consider in the application of these standards.

## ISSUES AFFECTING DEVELOPING COUNTRIES

The trends in technologies for mapping and GIS data collection towards digital data collection and will provide developing countries with new methods, that will have their advantages and disadvantages. The new technologies will lead to more rapid acquisition of terrain data, but the technologies will be expensive to acquire and they will require new levels of education and training.

For example, the new sources of image data, such as those from the high resolution satellites will be expensive to acquire and indeed, may prove out of the reach of most developing countries. The digital aerial cameras being developed will also be very expensive to acquire until their costs of development have been written-off. Terrain laser scan systems will be of great advantage to developing countries, since they acquire elevations accurately and rapidly. However, these systems

require special expertise to operate and hence surveys with them are likely to be undertaken by agencies at least in the short term.

The application of the new digital photogrammetric equipment for data acquisition requires new education and training of existing staff on their operation. Experiences in developing countries are that there is a considerable level of training required before these systems become operational. Similar periods will be required for developing countries to gain expertise in their use.

Technology transfer, maintenance of equipment and their regular replacement by upgrades will also be an issue, when this equipment is introduced into a mapping organization.

There will be significant long term benefits to the introduction of the new technologies into developing countries, since new data will be available and mapping from it will be more rapid and accurate. However, until the funding is available to purchase these systems and adequate training of personnel in their use is available, developing countries will have difficulties in taking advantage of these new technologies.

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United Nations E/CONF.93/BP/6

Economic and Social Council

Distr.: Limited
14 December 2000

English only

**Seventh United Nations Regional Cartographic Conference for the Americas**
New York, 22-26 January 2001
Item 7 (a) of the provisional agenda*
**Reports on achievements in surveying, mapping and charting in addressing national, subregional, regional and global issues, including policy and institutional issues**

# Spatial information management in the twenty-first century

**Submitted by the Federation of Surveyors****

* E/CONF.93/1.

** Prepared by Robert W. Foster, Matt Higgins and Jes Rytterstgaard, International Federation of Surveyors (FIG).

00-80794 (E) 100101

# SPATIAL INFORMATION MANAGEMENT IN THE 21ST CENTURY

**Robert W. Foster, Matt Higgins, Jes Rytterspaard**
**International Federation of Surveyors**

## INTRODUCTION

In the paper "The Digital Earth", written by the American vice president Al Gore you can find the following:

"A new wave of technological innovation is allowing us to capture, store, process and display an unprecedented amount of information about our planet and a wide variety of environmental and cultural phenomena. Much of this information will be georeferenced. The hard part of taking advantage of this flood of geospatial information will be turning raw data into understandable information".

New technologies will give us new methods for data capture. Remote sensing will give us cheaper data. Real time positioning will revolutionise the traditional fieldwork, etc. The available data will be used as well in public and private administration as in business. Data from different sources and data with different accuracy will be used in new combinations.

To optimize and rationalize the use of data national and regional users, as well public as private, will demand nationwide homogeneous data sets. In a few years no one will think of spatial data as something special. Spatial data will be integrated in all kinds of information systems.

Some of the preconditions for successful implementation of spatial data in society are the establishment of a Spatial Data Infrastructure and comprehensive knowledge on organizational structures, technological developments and data-collection methods.

## SPATIAL INFORMATION AND SUSTAINABLE DEVELOPMENT

Agenda 21 and The Habitat II Global Plan of Action address the need for information, development of appropriate databases and exchange of information as conditions for creating the basis for sustainable development in all regions of the world. One reason for this is that the global society faces great problems concerning urbanisation and the influence of urbanisation on coastal zones and environmental conditions overall. The ongoing development includes globalisation of both environmental problems and trades.

It is generally accepted that Spatial Information is an indispensable part of the basic infrastructure in the individual country. Again and again it is stated that spatial information affects 80% of human decisions making.

Spatial Information is a resource on a par with employees, funds etc. Use of spatial information produces a direct or indirect possibility of increased efficiency in all sectors of public administration, in the political decision-making process as well as in the private sector.

Regardless of the stage of development, there are innumerable applications for spatial information. The following are some examples of major, but also very different, areas of application:

- transportation infrastructure in a region,
- health monitoring programmes,
- cadastre projects,
- land management and spatial planning,
- socio-economic issues,
- monitoring of environmental issues
- environmental impact assessment
- conservation projects,
- natural resource management.

This variety of applications means that the users have very different backgrounds. There will be a need for comprehensible instructions on the possibilities and limitations of data from the individual data collections and there is a need for user-friendly, efficient distribution systems.

Spatial Information Management becomes an important discipline in both developed and developing countries and in countries in transition.

## SPATIAL DATA INFRASTRUCTURE

Administrators and politicians are beginning to recognise spatial information as well as a national resource as a part of the basic infrastructure that needs to be efficiently co-ordinated and managed in the interest of the nation. It is very important to develop policies for standardisation, legal aspects, pricing, distribution, etc.

Spatial Data Infrastructure is conceived to be: *an umbrella of policies, standards and procedures under which organisations and technologies interact to foster more efficient use, management and production of spatial data.*

The FIG Commission 3 has on the background of the recent developments among others gathered the following experiences and visions on spatial data infrastructure.

### Experiences

- National Spatial data Infrastructure (NSDI) is an asset for all nations in general. It should be considered as a key part of wider infrastructure assets such as roads, telecommunication networks etc.
- Establishing of a Spatial Information Infrastructure demands co-operation/partnership between the public and the private sectors and amongst the variety of professions involved.
- Given the complexity of existing institutional structures, one can expect conflicts when seeking co-operation in NSDI strategy formulation and implementation.

- NSDI can proceed even if a formal policy document (top down approach) does not exist. It is possible to proceed with certain operational level activities (bottom up approach) while the policy is being formulated. These activities can themselves drive and encourage policy.
- Every NSDI will be different, depending on cultural needs, social evolution, economic reality and national ambitions. The environmental framework and the market demand will shape the most appropriate SDI.
- NSDI policy must be flexible to address rapidly changing needs and wishes of the users and adapt to changing technologies.
- Varied applications and services through a project-oriented approach will bring reality to the NSDI. An over emphasis on data acquisition, without a market linked application, will not provide any momentum for further development.
- Visualisation, modelling and analysing activities will be the focus of value added services in the years to come.

**Visions**

- Cadastral, topographic and thematic datasets should adopt the same overarching philosophy and data model to achieve multi-purpose data integration, both vertically and horizontally.
- To be able to integrate and share data we need to focus on research to understand and resolve different semantics in data.
- To be able to offer the different users (institutional as well as private) the full potential of spatial information independent of space and time, the full range of spatial data, actual as well as historical, should be made accessible and available.
- Alternative possibilities for the presentation and interpretations of spatial information, including integration of knowledge, should be considered.
- The commercial and contractual frameworks for co-operation and the associated business models will be key issues in the further development of NSDI.
- To be able to adapt to the e-market rethinking of pricing, rights and access to data is necessary.

## ORGANISATIONAL ISSUES

For a long time, EDP was used primarily to automate known working processes. With the available information technology, it is now realistic to reassess working processes and co-operation models. Now it is possible to create models across the existing administrative borders, as well as across borders between the public and private sectors.

Information technology makes it possible to separate authority from administration. It is possible to outsource parts of the public administration, and to involve the private sector in the establishment, operation and updating of the basic geographic and alphanumeric data collections.

Introducing information technology is so crucial to an organisation that the responsibility for the implementation has to be deeply rooted in the top management.

Unlike other resources, spatial information does not suffer any wear from repeated use. Different investigations show that the real benefit of investments in spatial data increases dramatically with the multiple use of data.

Multiple use demands co-operation between the primary user and other possible users on common data models, object definitions, common identification, keys, etc., even agreements that one agency is to take care of data necessary for another agency.

With the modelling, analysis and visualisation possibilities inherent in even cheap GIS solutions, it is now possible to present plans, solution proposals, etc. in a form which does not require great reading skills, etc. This means that it is becoming possible to involve citizens even if they lack the requisite educational background.

The use of spatial information creates transparency in the decision-making at the same time, this implies better service for politicians, NGOs and citizens, and efficient support for the democratic process.

Information technology offers many possibilities for establishing efficient communication and distribution of information. This also applies in those parts of the world where the general communications infrastructure is developed only to a limited extent.

With Internet technology and by using the WWW, it is possible, at the same time, to create cheaper solutions at national level and to open up existing data collections to the outside world.

## THE EDUCATIONAL CHALLENGE

As well developing countries as countries in transition are facing problems such as capacity building and the lack of a developed private surveying community. Often they experience an intensive brain-drain.

In this way the individual country becomes very dependent on international consultancies and contractors, and it is nearly impossible for surveyors to establish the basis for sustainable business.

Education is a real bottleneck. It is very urgent to establish sufficient possibilities for education and training on all professional levels. Hitherto it has been necessary to send key employees on training and education stays in donor countries, at international training centres, etc. The new technology offers completely new possibilities for training and education. Distance learning and distance training are becoming important strategic parameters in developing countries. It is now possible to offer training and education on site at all levels

with whichever specialists might be required. This will minimise implementation times. At the same time, it will be possible to be less dependent on key persons because it will not be costly to involve more employees in the training and education. The individual country should be very much aware of the distance learning activities e.g. in some of the former eastern European countries.

The traditional employee with a medium or high level education in geo-related issues does have a comprehensive knowledge on IT and informatics, cartography, photogrammetry and surveying.

At the same time there is a need for employees with new qualifications such as management, standards, data models, meta data, access to data, infrastructure architecture, intellectual property right, copyright, prizing of data and organizational developments. Beside there is a need for knowledge on analysis, modelling, visualization, visual communication etc.

## TECHNOLOGICAL DEVELOPMENTS

Information technology plays a very important role as a tool for use and integration of data both at local and national level. The tools are as well used to create a model of a part of the world and, as they are used for manipulation, analysis and visualisation purposes.

For a long time cost-intensive technology has been a barrier to effective utilisation of information technology. To day the tools are cheap mass-produced hardware and standard software like databases, spreadsheets, etc

This trend towards cheaper, simpler solutions is continuing. With Internet and intranet technology it is possible to make data and information available in an inexpensive way to both traditional users and new groups of users, including individual citizens. Internet technology makes it possible to open up traditional archives to interested users. Web-GIS in which the users handle geographic information using standard Web browsers is a reality.

## SPATIAL DATA AND SPATIAL INFORMATION

High costs are involved in the establishment and maintenance of the necessary spatial data. Therefore, many people are endeavouring to utilise alternative methods for collecting data and to use other data types.

To facilitate and minimise costs in connection with changes in technology it is essential to use robust data models and as far as possible it is best to base developments on internationally approved or de facto industry standards, data-exchange formats, etc.

The costs are very dependent on the level of ambition. On account of both the high initial costs and the long implementation periods, in a preliminary phase it is an idea to divide the future use of spatial data and spatial information into three groups: planning, administration and projects.

For planning purposes, low-cost and short production time is more important than accuracy and completeness. For administration, the focus is on the completeness of specific themes or objects and on the possibilities for updating. Project data is normally characterised by high demands on accuracy and the content of specific details. In contrast to administrative data, planning and project data has a limited lifetime.

## SPATIAL INTEGRATION

The capabilities of data collection technologies along with the demands of GIS and the extension of SDI concepts will require high levels of spatial integration. However, it is difficult to predict what other data a user may want to integrate. Therefore, data itself will need to be as "integratable" as possible by being in a common reference system and to a known quality.

## INTEGRATION OF TECHNOLOGIES

The digital nature of the technologies will enable them to be integrated to mitigate each other's shortcomings. This can already be seen at several levels. At the international level we see collocation of various complementary observation techniques such as very long baseline interferometry, satellite laser ranging, absolute gravimetry, high precision tide gauges and satellite positioning. So called mobile mapping systems are bringing imaging and scanning technologies together with satellite and inertial positioning (in airborne, marine and vehicle platforms). At the level of the survey party we see integration of total stations and real time satellite positioning. As well as physical integration in the field, there is also much effort going into integration at the data processing level, under headings such as data fusion.

## SOME SPECIFIC TECHNOLOGICAL DEVELOPMENTS

Specific technologies must reach a certain level of maturity before integration can be considered. In parallel with integration developments then, it is also important to watch the development of individual technologies. That enables one to keep technological developments in perspective and select the appropriate data collection technology for a given task and a given budget.

With that in mind and looking to future technologies, an overriding trend will be continued development of space based technologies. A new generation of imaging satellites is coming that will cover a range of spectral and spatial resolutions, including metre level resolution. A spectacular example is the recent Shuttle Radar Topography Mission that produced global topographic data and a global DEM over 80% of Earth's land mass (between 60°N and 56°S) during an 11-day flight.

Satellite positioning will continue to have a profound effect on data collection techniques. The Global Positioning System (GPS) will continue to hold centre stage for some time but influences beyond GPS alone will begin to have impact under the more generic term, Global Navigation Satellite Systems (GNSS). Developments we are already seeing include the growing importance of the Russian GLONASS system, the development of augmentations systems (ground and/or space based) and the European community's desire for more influence through its Galileo program.

Within GPS itself, a major milestone has been the removal of selective availability (SA) leading to major improvements in the accuracy available for point positioning using inexpensive handheld receivers. This is just the first in many improvements planned for GPS. Developments under the heading of GPS modernisation, include adding a second civil frequency and eventually a third frequency; improvements that will bring increased accuracy and reliability for all users.

These changes will not bring a significant increase in the accuracy of GPS Surveying, already at the centimetre accuracy end of the market, but the additional frequencies will improve reliability. The major influence on GPS Surveying in coming years will be the continuing trend to the so-called real time kinematic technique (RTK). Networks of permanent stations supporting real time and post processed GPS surveying will be increasingly important parts of the Spatial Data Infrastructure.

As well as these newer technologies, traditional data collection technologies like total stations and levels will continue to improve. Like everything else, these technologies will become increasingly digital and allow for easier integration of the data sets gathered. Improvements to the supporting software will assist in this regard with tighter integration of GIS and surveying software.

## ASPECTS OF SDI TO SUPPORT DATA COLLECTION

It will be important for Spatial Data Infrastructure to recognise and support these developments in data collection. At the softer end of the infrastructure, work is required to ensure that the appropriate technical standards and specifications are in place. Any data collection can then be carried out to these standards and specifications and according to processes that enable compliance.

Another important part of any SDI is the spatial referencing system that ensures all positions conform to well defined horizontal and vertical datums and to a known quality. As outlined earlier, this ensures data is as "integratable" as possible. The spatial referencing part of the SDI includes geodetic reference marks, supplemented to an appropriate degree with GPS base stations. The system also includes databases and mechanisms for accessing the required spatial referencing information. A major task for spatial referencing is making local datums more compatible with the International Terrestrial Reference Frame and thus with WGS84 as used in GPS. As well as horizontal datum improvements, this includes the need for appropriate geoid models to enable accurate height measurement using satellite positioning. Looking further into the future, countries such as Japan and New Zealand, where crustal deformation is an issue, are realising that the fourth dimension of time will be increasingly important in their spatial referencing system.

## SENSITIVITY TO CULTURAL HERITAGE AND ENVIRONMENTAL ISSUES

Moving on from the SDI into applications, there is increasing demand for data collection processes that are sensitive to cultural heritage and environmental issues. On a global scale, geodetic knowledge is combining with many other disciplines to help understand global processes. Satellite radar altimetry is being used to measure sea surface height and temperature; vital to understanding climate variation. Satellite geodesy is monitoring the stability of high precision tide gauges that are measuring sea level variations linked to global warming.

On local and regional scales, non-invasive remote sensing technologies like photogrammetry and spectral and laser scanning are already in use in applications ranging from archaeological sites to assessing tree canopy cover to finding routes through culturally or environmentally sensitive areas. These technologies may be deployed on land and marine vehicles, in aircraft or satellite based.

## AREAS OF CONFLICT

Such non-invasive technologies also have utility in areas where security of personnel is an issue and direct data collection techniques may be logistically difficult or even dangerous. This would include areas of current conflict or areas of past conflict that may have the unwelcome legacy of land mines.

## CONCLUSIONS

It is our duty to promote sustainable development. This requires us to be unprejudiced and to have an overview. We create the overview by, among other things, monitoring developments and continuously analysing results. Information technology is indispensable, but data and information are a prerequisite. There is a great need for spatial information. However, this is not solely a question of information. There is a very significant management element. Spatial Information Management is becoming a major area of work for surveyors throughout the world.

The FIG working on the issues raised in this paper and on their application at the local, regional and international level. The specialist commissions of FIG are well placed to develop practical and appropriate best practices in spatial information management. The member organizations of FIG can be strong advocates of those best practices in their countries of interest. FIG also recognises the need to act at the regional and international level through

cooperation with allied professions and with agencies of the UN and through its forums like the regional cartographic conferences and the permanent committees on GIS infrastructure. These actions demonstrate that the surveying profession is committed to spatial information management in support of the sustainable development of our "Digital Earth".

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